



Gear and Flaps Down - Part 2

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In our previous discussion of the effects of lowering the gear and flaps (July/August 1995) we found that the velocity (TAS) for maximum glide distance $V_{L/D_{max}}$ decreases by approximately 16%, i.e., from 122 mph to approximately 103 mph for a model 33 Bonanza, if we assumed that lowering the flaps doubles the equivalent flat plate area f . We also found that the velocity for maximum glide distance decreased by approximately 24% to 93 mph if we assumed that lowering both the gear and flaps tripled the equivalent flat plate area.

We continue our discussion by asking what happens to the velocity for maximum rate-of-climb and to the actual rate-of-climb when we lower the flaps and/or gear. This is important when we have to execute a go around at the last minute – for example, when a cow walks out onto the runway when we are over the numbers at 20 feet. Don't laugh, it happened to me!

Again, the clue is to look at the effect of an increase in equivalent flat plate area on the power required versus velocity (TAS) curves. For completeness, recall from our earlier discussion that the equation for power required to maintain steady level flight is given by

$$P_r = \frac{\sigma \rho_{SL}}{2} f V^3 + \frac{2}{\sigma \rho_{SL}} \frac{1}{\pi e} \left(\frac{W}{b} \right)^2 \frac{1}{V}$$

where

- b is the wing span.
- e is the so called Oswald efficiency factor.
- f is the equivalent parasite drag area, or the equivalent flat plate area.
- W is the weight of the aircraft.
- V is the true airspeed (TAS).
- ρ_{SL} is the density at sea level.
- σ is the ratio of the density at altitude to that at sea level ρ/ρ_{SL} .

Furthermore, recall that the minimum power required to maintain steady level flight is given by

$$P_{r_{min}} = 2.48 \frac{f^{1/4}}{\sqrt{\sigma \rho_{SL}}} \left(\frac{1}{\pi e} \right)^{3/4} \left(\frac{W}{b} \right)^{3/2}$$

and the velocity for minimum power required by

$$V_{P_{r_{min}}} = \left(\frac{4}{3\pi f e} \right)^{1/4} \sqrt{\frac{1}{\sigma \rho_{SL}}} \sqrt{\frac{W}{b}}$$

Figure 1 shows power required vs velocity curves for the clean (labelled f and shown solid), gear down *or* flaps extended (labelled $2f$ and shown dashed) and gear *and* flaps down (labelled $3f$ and shown dotted) aircraft configurations.

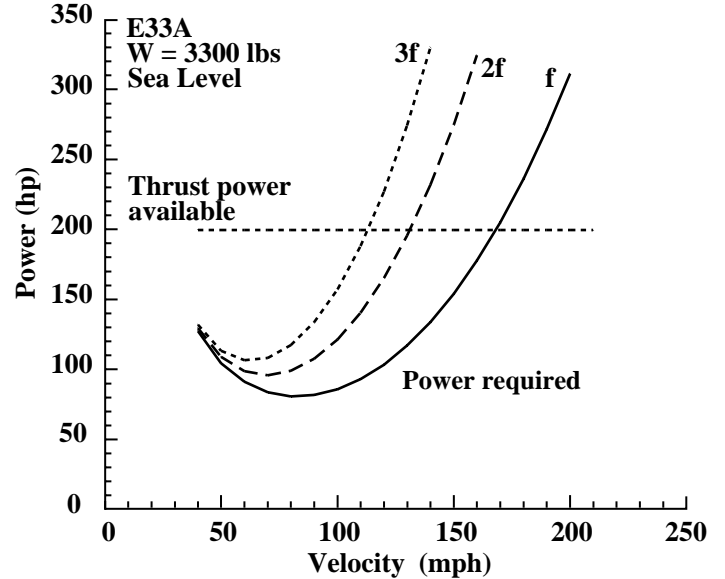


Figure 1. Thrust power available (constant) and power required versus velocity.

The rate-of-climb, RC , is given by the excess power available over that required to maintain steady level flight divided by the weight of the aircraft. Expressed as an equation this is (you knew I was going to do that)

$$\text{rate-of-climb} = \frac{\text{power available} - \text{power required}}{\text{weight}}$$

The rate-of-climb equation is not quite as simple as it looks. The power available is in fact the *Thrust Power Available*. The thrust power available is the power delivered by the engine and propeller combination. A propeller is not 100% efficient in converting the power available at the engine propeller shaft to thrust. Consequently, we must account for propeller efficiency. The thrust power available, ThP_a , is the engine power at the propeller shaft, P_a , multiplied by the propeller efficiency, η (eta), i.e.,

$$ThP_a = \eta P_a$$

Thus, our rate-of-climb equation is

$$RC = \frac{ThP_a - P_r}{W}$$

For a given propeller, at a given RPM, the efficiency of the propeller depends on the velocity of the aircraft. However, as a first approximation we can consider the propeller efficiency to be constant. At the low velocities associated with a go around, the propeller efficiency is quite low. A good number is about 70% (see Fig. (2)). Therefore, to get an approximation to the thrust power available for a model 33A we multiply 285 hp by 0.7.

The result is 199.5 horsepower, that is, just under 200 horsepower. This is shown as a dotted straight line in Fig. (1).

Looking at Fig. (1) and recalling our rate-of-climb equation shows that the *maximum* rate-of-climb occurs for *minimum* power required at the velocity for minimum power required. Figure 1 also shows that the velocity for maximum rate-of-climb, given by the largest distance between the thrust power available and power required curves, *decreases* when the equivalent flat plate area, f , increases, that is, when we lower the gear and/or flaps. Our velocity for minimum power required equation then shows that the ratio of $V_{RC_{max}}$ dirty, i.e., with gear and/or flaps down, to that in the clean configuration is

$$\frac{V_{RC_{max}} \text{ (dirty)}}{V_{RC_{max}} \text{ (clean)}} = \left(\frac{f_{\text{clean}}}{f_{\text{dirty}}} \right)^{1/4}$$

Recall that lowering the gear or flaps approximately doubles the equivalent flat plate area, f . Thus, with the gear down or the flaps extended

$$\frac{V_{RC_{max}} \text{ (dirty)}}{V_{RC_{max}} \text{ (clean)}} = \left(\frac{1}{2} \right)^{1/4} = 0.84$$

which shows that $V_{RC_{max}} \text{ (dirty)}$ decreases by approximately 16% from the clean configuration.

Lowering the gear and extending the flaps to 30° approximately triples the equivalent flat plate area, f . For this configuration

$$\frac{V_{RC_{max}} \text{ (dirty)}}{V_{RC_{max}} \text{ (clean)}} = \left(\frac{1}{3} \right)^{1/4} = 0.76$$

which shows that $V_{RC_{max}} \text{ (dirty)}$ decreases by approximately 24% from the clean configuration. These are significant effects. Notice that these are exactly the same factors by which the best glide velocity decreases when the gear and/or flaps are extended.

What these results tell us is that with gear down and flaps extended the aircraft must be flown at the correct (lower) velocity to achieve the maximum rate-of-climb.

We now want to investigate the effect of flying the aircraft at the incorrect velocity for the maximum rate-of-climb. To do this we need to more accurately consider the variation of propeller efficiency with velocity. For a typical McCauley 80 inch diameter constant-speed three blade propeller, the propeller efficiency, η , at full throttle and 2700 rpm at sea level is shown in Figure 2. Notice that the efficiency is quite low at low velocities and reaches a maximum of about 88-90% for typical cruise velocities. The effect of the variation of propeller efficiency with velocity on the curve of thrust power available is shown as the dotted line in Fig. (3).

Recalling the rate-of-climb equation shows that taking the difference between the thrust power available curve and the power required curves at a given velocity and dividing by the weight yields the rate-of-climb at that velocity.

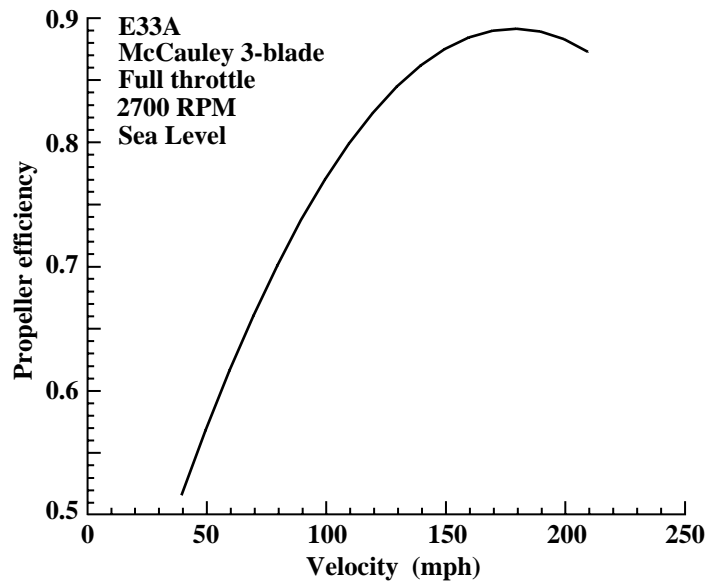


Figure 2. Propeller efficiency versus velocity.

The rate-of-climb curves for the clean configuration (labelled f and shown solid), gear down *or* flaps extended (labelled $2f$ and shown dashed) and gear *and* flaps down (labelled $3f$ and shown dotted) are given in Fig. (4). Zero rate-of-climb is indicated by the horizontal dotted line. Because of the variation of propeller efficiency with velocity the velocity for maximum rate-of-climb is higher than given by our earlier approximate results.

For example, with gear down and flaps extended our results indicate that maximum rate-of-climb is approximately 810 fpm at approximately 89 mph. However, the POH (old version) gives the velocity for best rate-of-climb gear and flaps down as 77 mph. Our results appear to be about 13% too high. The explanation is that our rate-of-climb equation does not account for the upward inclination of the thrust produced by the propeller nor for the effect of the propeller slip stream on the wing. The detailed analysis is too complex to go into here, but we can estimate the effects of propeller thrust indirectly. For an E33A the POH (old version) gives the gross weight stalling velocity gear and flaps down power off as 61 mph and power on as 46 mph.

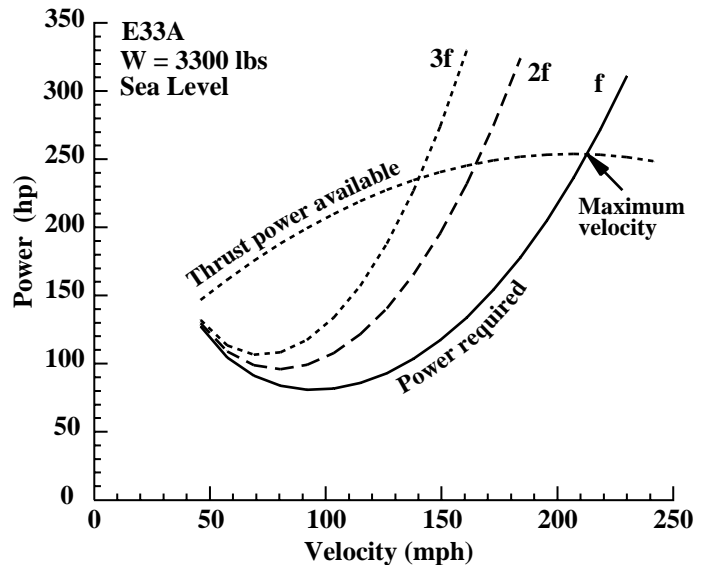


Figure 3. Power available (variable) and power required versus velocity.

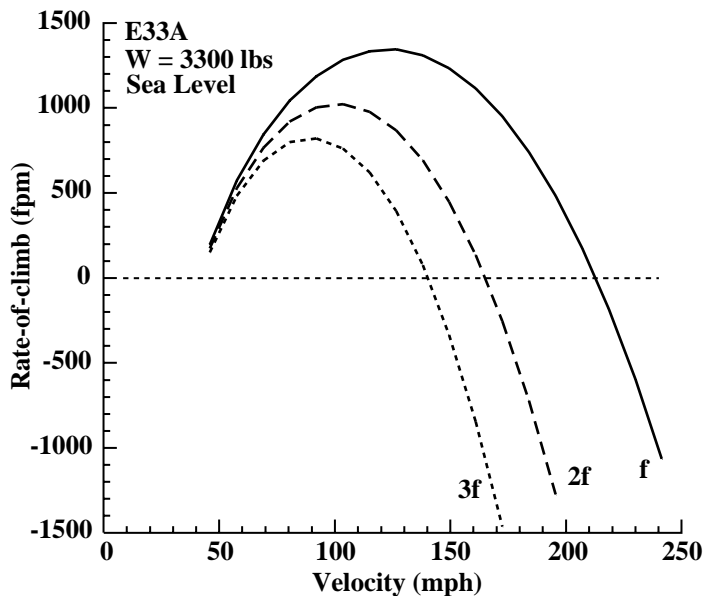


Figure 4. Rate-of-climb versus velocity.

The corresponding values for gear and flaps up are 72 mph and 57 mph. Thus, the effect of power is to reduce the stalling velocity 20-25%. Because the velocities for maximum rate-of-climb are higher than the stall velocities, the effect of power is decreased by about 50%. Using a 13% reduction in the calculated velocity for maximum rate-of-climb yields the value given in the POH. Incidentally 77 mph is the experimental value for 4000 feet published by Taylor and Guinther in *Positive Flying*,⁺ a book that I recommend.

What is most important from all this discussion is to note that flying at either too slow or too high a velocity degrades the climb performance. Also, note that maximum rate-of-climb occurs for a significantly *lower* velocity with the gear and flaps extended than in the clean configuration. Finally, a word of caution. In order to simplify the discussion I make assumptions, for example above I neglected the effects of thrust inclination on the rate-of-climb. Consequently, the *numbers* that result are not always exact. Thus, you should follow the procedures in the POH; after all, Beech has more complete data. The principles are the most important result.

For operational considerations, note that as we clean up the aircraft by retracting the gear and flaps we need to allow the aircraft to accelerate to a higher velocity to achieve maximum rate-of-climb. Because flap retraction speed is generally slower than gear retraction speed for a model 33, and opening the inner gear doors to retract the gear increases the drag, these results indicate that we should retract the flaps first and then the gear as we clean up the aircraft and allow it to accelerate and simultaneously adjust the pitch to maintain the velocity for maximum rate-of-climb.

Fortunately, for those of us who fly with the 285 hp engine there is a wide range of velocities that result in a positive rate-of-climb in the dirty configuration *at sea*

level. However, as the density altitude increases the rate-of-climb versus velocity curves (in terms of indicated airspeed) essentially move downward. The result is a narrowing of the range of velocities that achieve a positive rate-of-climb. Further, there is an altitude above which the aircraft will *not* climb in the dirty configuration. Thus, precise speed control and attention to cleaning up the aircraft become more important. We'll look at density altitude effects the next time.

⁺ Richard L. Taylor and William M. Guinther, *Positive Flying*, MacMillan, New York, 1978.